Contents lists available at www.goldenlightpublish.com/journals/jcemi/2-toc

Journal of Construction Engineering, Management & Innovation

Journal homepage: www.goldenlightpublish.com/journals/2/jcemi

Impact of VR-based climate change education on awareness and water use behavior

İlker Baki Alkan[1,*], Hasan Basri Başağa[1,2,3]

[1] Karadeniz Technical University, Department of Civil Engineering, Trabzon, Türkiye
[2] Earthquake and Structural Health Application and Research Center, Karadeniz Technical University, Trabzon, Türkiye
[3] Northsign Design Software Construction Trade Ltd. Co., Trabzon, Türkiye

[*] Corresponding author: İ. B. Alkan (ilkerbakialkan@gmail.com)

https://doi.org/10.31462/jcemi.2026.745
Received 07 June 2026; Revised 6 September 2026; Accepted 14 September 2026; Available online 22 September 2026

Keywords
Virtual reality
Education
Climate change
Water

Abstract

Climate change has increased the need for effective educational approaches that can promote climate-related awareness and environmentally responsible behaviors. This study investigates the effects of a passive 360-degree virtual reality educational intervention on climate change awareness and operational water consumption in a real industrial setting. The study was conducted with 17 cafeteria workers at an operating factory in Türkiye. A VR-based educational video consisting of seven scenarios addressing climate change impacts, water scarcity, and water-saving practices was developed using Unity and experienced by the participants using an Oculus Quest 2 headset. Climate change awareness was assessed using a validated 5-point Likert scale administered one month before and one month after the VR intervention. In addition, the cafeteria's total hot and cold water consumption was monitored for one week before and one week after the intervention. The mean climate change awareness score increased from 39.24 (SD = 4.67) before the intervention to 41.65 (SD = 3.08) after the intervention, with a statistically significant increase confirmed by both a paired-samples t-test and a non-parametric Wilcoxon Signed-Rank test ($p = 0.022$). Weekly operational water consumption decreased from 104.2 m³ before the intervention to 97.9 m³ after the intervention, corresponding to a reduction of 6.3 m³ (6.05%), which was confirmed to be statistically significant using a paired-samples t-test ($p = 0.042$). These findings indicate that passive VR-based climate change education can increase climate change awareness and is associated with reduced operational water consumption in a real industrial cafeteria setting.

1. Introduction

After World War II, while countries experienced growth, waste piles and environmental pollution also increased alongside the growth. The amount of CO_2 in the atmosphere was 300 ppm in 1950, reaching 420 ppm in 73 years. If the CO_2 level in the atmosphere reaches 1500 ppm, this level will not return to pre-industrial levels for tens of thousands of years [1].

Scientists have conducted various studies on why individuals and governments are not taking necessary measures regarding climate change. A study surveyed 9,000 people from 9 countries worldwide about their willingness to change their habits related to climate change. 46% of the participants stated that they do not need to change their habits and instead supported governments to take necessary measures [2, 3].

People don't pay enough attention to climate change measures because they see the threat as far away. If people don't feel a threat, they can't care about it enough, no matter how big it is [4].

If the effects of climate change can be narrated to people as if they are present, happening now, people can perceive climate change threats as concrete rather than abstract. Virtual reality technology is currently the forefront technology that can immerse people in the effects of climate change as if they were there. In virtual reality technology, a person typically navigates through a simulated environment using a headset. They interact with virtual objects in the simulated environment, completely disconnecting from the real environment [5].

Visuals can help people feel the threats of climate change more closely. This is because people react to visuals faster

eISSN 2630-5771

than to sounds. Amit et al. [6] conducted a series of tests and as a result of the study, pictures were identified as concrete representations bearing similarity to reference objects, while words were identified as abstract representations carrying the essence of objects. It was suggested that in climate change education, enriching the education with visuals instead of using words can enhance people's concrete perceptions. In the context of environmental literacy, recent literature emphasizes that the unique affordances of VR, such as immersion, presence, and embodiment, play a critical role in bridging the psychological distance of global warming and overcoming psychological barriers related to climate mitigation [7]. This study aims to use virtual reality technology, one of the leading technologies of our time, as a tool to help people better perceive the threats of climate change.

This study aims to use virtual reality technology, one of the leading technologies of our time, as a tool to help people better perceive the threats of climate change. As demonstrated by recent educational and infrastructural applications of immersive systems, these technologies provide effective virtual environments that bypass traditional constraints [8]. Building upon this premise, this study aims to use virtual reality technology, one of the leading technologies of our time, as a tool to help people better perceive the threats of climate change and translate this awareness into tangible sustainable behaviors.

1.1. Literature review

Research studies that utilize virtual reality technology for the purpose of mitigating climate change were examined in order to define the boundaries of this study utilizing virtual reality technology. In order to review the studies conducted in this field in the literature, the Web of Science database, known for hosting numerous scientific journals and being closely monitored by researchers, was utilized. In the advanced search options of the database, the article criteria were searched for the keywords "climate change" and "virtual reality" in the abstract section. The abstracts of the resulting 70 articles were examined, and 19 articles were identified where virtual reality technology was used for climate change education purposes or to increase awareness of climate change. The full texts of these 19 articles were examined. In this section, information will be provided about the content of these 19 articles that have been reviewed in full.

In literature, there are studies utilizing the feature of virtual reality technology to transport users to a different environment. Schott [9] developed an application where students could virtually explore the Fiji Islands, where the threats of climate change are visible, using virtual reality technology. The study reported that students had a productive experience, and numerically indicated that the virtual reality experience resulted in much lower carbon emissions compared to actual travel. Petersen et al. [10] enabled their students to explore Greenland using virtual reality headsets, providing them with the opportunity to observe changes in the glacier mass.

Researchers working in this field have shown significant interest in simulating the effects of floods and rising sea levels. Rismayani et al. [5] conducted a study on the Makassar region, which has a considerable risk of flooding because of climate change but lacks sufficient knowledge among its residents about flooding. Calil et al. [11] displayed the rise in sea levels due to climate change to participants using virtual reality technology. Yavo-Ayalon et al [12] presented participants with a simulation where a submerged city was toured by bus during an actual bus tour. Dhunnoo et al. [13] presented experts with a virtual reality simulation of a submerged city. In line with these approaches, recent experimental evidence demonstrates that delivering future climate scenarios and sea-level rise through immersive VR simulations provides more effective correction outcomes by significantly enhancing certainty in climate realities and reducing skepticism compared to traditional media platforms [14].

Forest fires and virtual forest simulations have also become topics of interest for researchers utilizing virtual reality technology as a tool for climate change education. Meijers et al. [15] simulated a forest fire using virtual reality technology and video. One group of participants watched the fire through video, while another group experienced it through virtual reality technology. Chandler et al. [16] modeled a forest ecosystem in Austria using VR technology. Huang et al. [17] simulated the 50-year evolution of a forest using virtual reality.

Driven by the recent shifts in educational technologies, global collaborations have started to employ immersive environments to visualize climate degradation. A cross-cultural study integrated 360° VR photosphere photographs into ecology curricula, enabling users to witness local ecological crises such as drought and habitat loss. The immersive exposure was reported to be highly transformative in visualizing complex ecological concepts, enhancing emotional engagement, and driving behavioral shifts toward climate advocacy [18].

Many researchers utilizing virtual reality technology as a tool for climate change education have employed their simulations in classroom settings for student instruction. Aksel Stenberdt and Makransky [19] showcased waste management education designed with virtual reality technology to students. Cai et al. [20] developed a virtual reality application aimed at addressing environmental issues and provided students with a five-minute experience. Calvert and Hume [21], designed a virtual reality education regarding the reduction of polar ice mass. Newton et al. [22] unlike other studies in the literature, compared climate change education designed with virtual reality technology to climate change education designed with augmented reality technology for comparison. Lo and Tsai [23] designed virtual reality

education as environmental conservation course material for their students.

Additionally, in certain studies, virtual reality technology has been utilized to educate about the impact of climate change on ocean acidification. Markowitz et al. [24] and Queiroz et al. [25] designed virtual reality educations focusing on ocean acidification.

A study that differs from other research was conducted by Vassilopoulos et al. [26]. The researchers instructed small business owners to make investment decisions after providing specific information. Subsequently, they showed them climate change education using virtual reality technology and asked them to reconsider their investment decisions.

In two studies in the literature, climate change content prepared with virtual reality technology has been examined as an alternative to media and news sources. Thoma et al. [27] conducted a study on whether virtual reality simulations are more effective than traditional media. Barnidge et al. [28] produced climate change news using virtual reality technology and examined whether their produced news affected learning.

1.2. Purpose of the study and research questions

When examining the studies in the literature on the use of virtual reality technology as an educational tool for climate change, it was found that none of the studies were specifically aimed at implementation in a section of a real industrial facility. The majority of the studies were designed for student education and public education. However, for the research to be applicable in everyday life, studies need to be adapted to industrial and factory fields. In alignment with the recent transition toward Industry 5.0, Sustainability Digital Twins (SDT) have also been proposed as complementary approaches for integrating sustainability-oriented information with interactive VR/AR platforms and supporting human-centric green practices in industrial environments [29]. Additionally, the studies in the literature have examined the satisfaction level, interface efficiency, and level of realism of the designed education. However, limited research has examined the impact of education on human behavior and awareness. In this study, behavior change has been addressed as a separate topic from awareness. Because, while awareness is a necessary condition for changing human behavior, it is not sufficient [30].

The study was conducted at the cafeteria of a real factory in Turkiye and the participants were cafeteria staff. Thus, the climate change education prepared was experienced by real workers in an actual operational setting. After experiencing the education, changes in the participants' awareness and their actions regarding climate change were observed. The analysis of water usage in the cafeteria before and after the education was used to assess the participants' behavioral changes. This study distinguishes itself from other studies in the literature both by being conducted in a real industrial facility and by examining human behavior.

The aim of this study is to determine whether the education provided through virtual reality technology alters people's perceptions of climate change and whether virtual reality technology education enables people to take additional measures regarding climate change. The study is focused on two different research questions.

First Research Question: Does the awareness of climate change increase among cafeteria workers who have received education through virtual reality technology?

Second Research Question: Does the overall operational water consumption of the cafeteria decrease after the VR education?

2. Method

The study was conducted in four stages, and the stages of the study are schematically presented in Fig. 1. This flowchart illustrates systematic progression from the initial preparation of the virtual reality education application, through the immersion stage, to the quantitative evaluation of both awareness levels and physical water consumption. In this section, each stage of the study will be explained in detail under topic headings.

2.1. Preparation of education

The correct preparation of virtual reality education with the right method is crucial for the study to yield accurate results. In the following subsections, the tools and methods used during education preparation are explained.

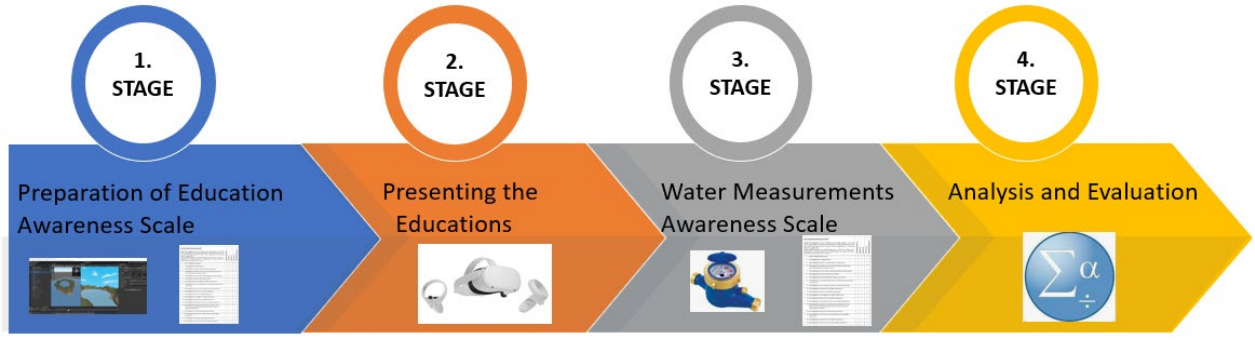

Fig. 1. Flowchart of the experimental research methodology and evaluation stages

2.1.1. Virtual reality modeling software selection

Scientists predominantly prefer the Unity Game Engine for content creation in comprehensive research in visualization technologies [31] preferred to use the Unity game engine when designing virtual reality training related to occupational safety [32] preferred to use the Unity game engine when creating an online virtual visualization training platform. One of the main reasons researchers chose the Unity game engine is its suitability for almost all operating systems [33]. Another advantage of Unity is its ability to provide users with extensive learning opportunities. Its documentation network is vast, and its library contains many free virtual models available to users [34]. Another reason for choosing the Unity game engine is the power of the C# programming language, allowing users to turn anything they want into a simulation and providing users with free alternatives.

2.1.2. Development of the virtual reality education application

When designing virtual reality education, the participants' level of familiarity with technology should be taken into account. The participants of the study had no prior experience with virtual reality. Thus, the education was designed in the form of a video stream that did not require control. If participants were required to accomplish specific tasks with a controller or manipulate the device throughout the education, they wouldn't have experienced a comfortable learning environment. Unity game engine's Timeline editor was utilized to achieve the specified seamless transitions and time adjustments.

The messages provided in the training content were carefully selected because, according to Christiano and Neimand [35] it is important to consider the principles of behavioral science when delivering messages if the goal of a study is to encourage people to adopt new behaviors. Otherwise, the opposite behavior may occur instead of the desired one. Firstly, the participants for awareness education should be as narrow as possible. The education should include clear actions and impactful messages, and a theory of change should be developed. To consider these rules of behavioral psychology, the number of participants in the study was narrowed down, and a study specifically for cafeteria workers was conducted. The education was prepared specifically for the participants by emphasizing their daily tasks. Short and impactful messages were delivered. Seven different scenes were designed to achieve these goals. The designed scenes are described below.

A simulation has been added to the beginning scene of the education, showing a rotating Earth in outer space with all the stars visible. This simulation briefly provides information about the threat posed by climate change to the Earth. The purpose of this simulation is to make an impactful visual introduction to the education and to guide the flow of education from general to specific. In the second and third scenes, the damage caused by humans to the Earth is simulated. This aims to enable participants to witness firsthand the harm humans inflict on the planet. In the second scene, participants observe deforestation and the extinction of species as they visit a forest. In the third scene, they see a lake drying up rapidly at a prominent point of the lake. In the fourth scene, there is a desert scene to represent the impact of climate change on Earth. After explaining the threats of climate change to Earth and individuals, the focus shifts to the responsibilities individuals need to take to mitigate these threats. For this purpose, a kitchen scene in a cafeteria is designed in the fifth scene. In this scene, processes such as dishwashing and filling pitchers are simulated to illustrate the correct and incorrect use of water. Returning to the desert environment in the sixth scene, the threats awaiting Earth if individuals do not fulfill their responsibilities are reminded. The educational flow returns to the space scene in the seventh scene, along with closing statements, concluding the education. The representative visuals of these consecutive educational scenes are presented in Fig. 2.

2.1.3. Experience of Virtual Reality-Based education

The climate change education prepared with virtual reality technology was experienced by the cafeteria workers of the factory involved in the collaboration. There are 17 workers in the cafeteria, including cooks, dishwashers, and service staff.

A room was allocated by the cafeteria management for education to be conducted during the day shifts. There was no briefing or verbal persuasion regarding climate change before or after the education. The participating workers were informed that only an education session on climate change and the amount of water consumed in the cafeteria would be provided, and this would be done using a virtual reality headset. After the education sessions, workers were asked questions about what could be done to reduce water waste in the cafeteria, and their responses were noted. No guidance, confirmation, or refutation was provided for the answers given by the participants. Images captured during the education sessions are presented in Fig. 3.

2.2. Climate change awareness measurement

It was decided to use a scale to analyze the change in cafeteria workers' awareness of climate change before and after the virtual reality education. A literature review was conducted to determine the scale to be used. In a study conducted by Ataklı and Kuran [36], a reliable measurement tool was developed to assess participants' awareness of climate change. This measurement tool was prepared using a 5-point Likert scale. Obtaining a high score indicates a high perception of climate change by the participant. Factor analysis was conducted to assess the construct validity of the measurement tool, and its validity was confirmed. Additionally, the reliability of the scale was evaluated using Cronbach's alpha coefficient, determining its reliability.

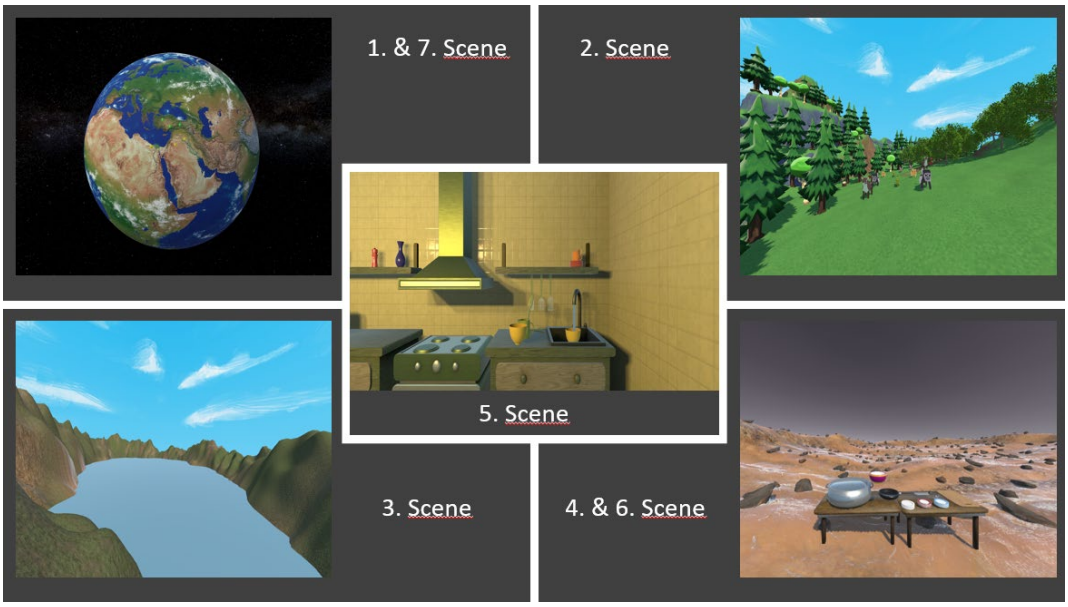

Fig. 2. Virtual reality climate change education scenes

Fig. 3. Cafeteria staff experiencing the immersive virtual reality climate change training sessions

The climate change awareness scale developed by Ataklı and Kuran [36] was administered to the participants one month before the training day. The same scale was then given to the participants one month after the training, and the changes in their scores were observed.

2.3. Waste water measuring

A two-week observation period was planned to determine the impact of the virtual reality-supported climate change education on the water consumption habits of the cafeteria staff. In line with the agreement made with the factory management, hot and cold water consumption in the cafeteria was monitored via separate water meters. The first week of this two-week observation covered the period immediately before the training, while the second week covered the period immediately after. The hot and cold water consumption data were recorded daily by the technical team and shared collectively with our working group at the end of each week.

Although external variables such as daily headcount, menu variations, and weather conditions can potentially influence water consumption, several measures were taken to ensure comparability between the monitored weeks. The cafeteria serves an average of 1,500 individuals daily, and it was verified that there were no reductions in personnel, factory shutdowns, or significant operational disruptions during the control weeks. Furthermore, the number of

equivalent workers and visitors was confirmed to be stable. Additionally, it was monitored that the menus utilized during the matched weeks required comparable water usage, and measurements were taken under similar weather conditions to ensure that external factors did not confound the observed changes in water consumption.

3. Results

Study examining the impact of virtual reality technology education on awareness and behavior is discussed under two headings:

1. Whether the virtual reality education increases people's awareness of climate change.

2. Whether virtual reality educations encourage individuals to take precautions against climate change hazards.

Two separate research questions were identified to support the two main topics focused on in the scientific study. Both questions were answered through evaluation of the analytical data obtained during the project. This section will present the numerical results and statistical analyses obtained.

3.1. Climate change awareness scale results

To answer the first research question at the core of the study, the change in the cafeteria staff's climate change awareness brought about by the virtual reality education was quantitatively evaluated. The scale results comparing the participants' pre- and post-education perception levels, along with the overall distribution of these results, are summarized in Table 1.

As can be seen in Table 1, out of the 17 participants who attended the climate change awareness education, 12 showed higher awareness scale scores after the education compared to before. The scores remained the same for three participants, while the post-education scale scores were lower than the pre-education scores for 2 participants.

The significance of the scale scores obtained was evaluated through statistical analysis. Initially, the assumption of normality for the difference scores was tested using the Shapiro-Wilk test. Given that the data indicated a departure from normal distribution, both a paired samples t-test and its non-parametric alternative, the Wilcoxon Signed-Rank test, were conducted using the SPSS program to determine whether the climate change awareness education prepared with virtual reality technology influenced awareness, thereby ensuring the absolute robustness of the findings. According to the analysis results, the average test score of participants before receiving virtual reality education was determined to be 39.2353, while the average test score after receiving virtual reality education was 41.6471. The standard deviation of scores before education was 4.67, whereas it decreased to 3.08 after education. This decrease in standard deviation can be interpreted as participants approaching the full score more closely after the education. This is because the lowest score in the awareness test before education was 26, whereas it increased to 36 after education.

To test the methodological assumptions, a Shapiro-Wilk normality test was conducted on the difference scores, which indicated a departure from a normal distribution ($p<0.05$). Consequently, to ensure absolute robustness, both a paired samples t-test and a non-parametric Wilcoxon Signed-Rank test were conducted using the data entered into the SPSS program to investigate whether there was a significant difference between the pre- and post-education data at a 95% confidence interval.

The paired samples t-test resulted in a p-value of 0.022 ($p<0.05$), and the verification via the Wilcoxon Signed-Rank test similarly confirmed a statistically significant difference ($p<0.05$).

Table 1. Distribution of pre- and post-education climate change awareness scale scores of the participants

Participant Number	Pre-Education Scale Score	Post-Education Scale Score
Participant 1	41	41
Participant 2	42	44
Participant 3	26	38
Participant 4	43	45
Participant 5	43	44
Participant 6	36	44
Participant 7	35	44
Participant 8	42	44
Participant 9	35	36
Participant 10	43	44
Participant 11	35	38
Participant 12	43	44
Participant 13	*40*	*36*
Participant 14	43	43
Participant 15	43	43
Participant 16	*40*	*39*
Participant 17	37	41

These values, being less than 0.05 at a 95% confidence interval, indicate that there is a statistically significant difference between the pre- and post-education scale data. It has been concluded that there is a significant increase in participants' climate change awareness assessment scale scores after the virtual reality education.

3.2. Cafeteria water consumption results

The total water consumption data from the cafeteria of the collaborating company, one week before and one week after the training, is presented in Table 2.

When the values are examined, it can be seen that the water consumption recorded the lowest value on the day immediately after training. Although there was some increase in water consumption in the following days, the total amount of water consumed after the training is still lower than the amount consumed before the training. While a total of 104.2 m^3 of water was consumed in the week before the training, 97.9 m^3 of water was consumed in the week after the training. This means that in the week following the training, a total of 6.3 m^3 less water was consumed compared to the week before the training, and on average, 0.9 m^3 less water was consumed daily.

To evaluate the statistical significance of the daily water consumption reduction, a paired-samples t-test was conducted on the matched daily data (n=7 days). The analysis revealed a statistically significant reduction in daily water consumption ($t=2.58$, $p=0.042$).

4. Discussions

In this section, the significance of the study results and statistical findings will be examined, and they will be clearly related to the research questions. Discussions will focus on the impact of climate change education delivered through virtual reality technology on participants' awareness levels and its effect on water consumption behaviors.

4.1. The impact of virtual reality education on climate change awareness

According to the statistical analysis of the climate change awareness scale scores before and after the education, virtual reality education has increased participants' awareness. The majority of participants had higher climate change awareness scores after the education compared to before.

The awareness score of participant number 16 in the awareness scale has only decreased by 1 point compared to the previous test. Upon examination of this participant's test, it is observed that they scored 5 points on the "Concern for Climate Change" scale in the pre-education test and 4 points in the post-education test. The participant provided the same response for all other scale questions in both pre- and post-education tests. It is thought that the reason for the 1-point decrease in participant number 16's score might be due to momentary psychology.

In the conducted study, the first research question was " Does the awareness of climate change increase among cafeteria workers who have received education through virtual reality technology?" In the awareness scale filled out by the workers, a significant increase was observed after the education. Analytical results, and statistical analyses indicate that the awareness of climate change among cafeteria workers who received education with virtual reality technology has increased.

4.2. Water consumption behavior effect

The second and most novel dimension of the study constitutes the question of "whether the increase in awareness translates into a tangible behavioral change." The primary conundrum of traditional environmental education is its failure to reflect increased knowledge levels onto daily practices. According to this phenomenon, referred to in the literature as the "Knowing-Doing Gap," individuals caring about a problem or discussing it does not generally mean that they take real action [35, 37].

However, in this study, the objective and quantitative data obtained from the cafeteria water meters demonstrated that this general cycle in the literature was broken. While the total water consumption in the week prior to the training was 104.2 m^3, it decreased to 97.9 m^3 immediately after the training, yielding a net savings of 6.3 m^3 on a weekly basis (a daily average of 0.9 m^3) Although water consumption recorded its lowest level immediately after the training and exhibited slight fluctuations in the following days, the fact that the overall total remained permanently below pre-training levels indicates that a behavioral transformation was achieved.

This situation demonstrates that the sense of "vividness" and "presence" offered by VR technology reduces psychological distance in individuals.

Table 2. Quantitative comparison of cafeteria water consumption data before and after the virtual reality training

	Pre-Education							Post-Education						
	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14
Daily Total Water Usage	17.6	17.2	8.3	7.9	17.1	17.7	18.4	16.7	17.3	7.8	8.0	16.2	15.8	16.1
Weekly Total Water Usage	104.2 m^3							97.9 m^3						
Weekly Average Water Usage	14.89 m^3							13.99 m^3						

Because the participants directly experienced the impacts of the climate crisis in a virtual environment, they directly associated seemingly mundane water-wasting behaviors, such as leaving the tap running after the training, with the threat of global drought. Consequently, this study concretely demonstrates for environmental activists, educators, and corporate managements that even a passive 360-degree VR video—despite lacking controller-based interaction—can effectively reduce psychological distance and foster sustainable behavioral change. While this passive format limits user navigation compared to fully interactive VR environments, its immersive nature provides a compelling alternative to traditional methods such as brochures, seminars, or standard videos, proving valuable for operational integration.

5. Conclusions

In this study, the effect of climate change education prepared based on virtual reality on the amount of water usage by workers and whether there is any change in climate change awareness has been investigated. For this purpose, a climate change education prepared with virtual reality technology was shown to the cafeteria staff of a factory. Whether there was a change in the climate change awareness of the workers after watching this education was measured with a climate change awareness scale developed by Ataklı and Kuran [36]. In addition, water usage data were collected at the factory operation one week before and one week after the climate change education, and whether there was any change in water consumption was observed.

The study addressed two research questions. The first one is " Does the awareness of climate change increase among cafeteria workers who have received education through virtual reality technology?" Participants scored an average of 39.24 points on the climate change awareness scale administered before the education, which increased to 41.65 points after the education. A paired sample t-test conducted in the SPSS program revealed a significant difference in participants' awareness scores. Based on these findings and analyses, the research question has been answered as follows: "The climate change education prepared with virtual reality technology increases participants' awareness of climate change.

The second research question of the study is “Does the overall operational water consumption of the cafeteria decrease after the VR education?”. To answer this research question, cafeteria water consumption data were collected. According to these data, 104,2 m3 of water was used in the cafeteria in the week before the education, and this amount decreased to 97,9 m3 after the education. It was determined that the weekly water usage decreased by 6.3 m3 after the education. Based on the results obtained, the research question is answered as follows: "Climate change education prepared with virtual reality technology can reduce cafeteria workers' water consumption."

In this study, it was found that the education created with virtual reality technology increased participants' awareness levels. It was also observed that the virtual reality education changed the participants' water usage behaviors. Unlike similar studies in the literature, the study investigated not only the effects of virtual reality technology education on awareness levels but also its impact on human behaviors. In this regard, the study has brought a new perspective to the literature.

Declarations

Conflict of Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

This research received no external funding.

Author Contributions

İ. B. Alkan: Conceptualization, Methodology, Software, Validation, Formal Analysis, Investigation, Resources, Data Curation, Writing–Original Draft, Visualization, Project Administration. H. B. Başağa: Conceptualization, Writing–Review & Editing, Supervision.

Acknowledgments

The authors would like to express their sincere gratitude to Ekrem Yavuz Yıldız (Technical Manager of the facility) and Merve Salar (Cafeteria Manager) for their administrative support and coordination during the field studies. Special thanks are also extended to all cafeteria staff members for their valuable contributions and active participation throughout the training and data collection processes. The authors also confirm that informed consent was obtained from both the employer and all participating employees prior to the study, and that participation was voluntary.

Data Availability Statement

The data presented in this study are available on request from the corresponding author.

Ethics Committee Permission

The questionnaire survey and experimental procedures were approved by the Karadeniz Technical University Ethics

Committee for Natural and Engineering Sciences (Meeting Date: March 26, 2025, Meeting No: 63, Decision No: 4).

Use of Generative AI and AI-assisted Technologies

The author(s) confirm the author(s) did not use any AI tools in the preparation of this work OR research OR study.

References

[1] NASA (2023) Graphic: The relentless rise of carbon dioxide – Climate Change: Vital Signs of the Planet. NASA. https://climate.nasa.gov/climate_resources/24/graphic-the-relentless-rise-of-carbon-dioxide/. Accessed 1 Jan 2024.

[2] Riviere E (2021) Sharing the responsibility for climate action - PUBLIC Journal 04. https://kantar.turtl.co/story/public-journal-04/page/3/1. Accessed 7 Jan 2024.

[3] Yoder K (2021) Survey: 46% of people don't want to change their habits for the climate | Grist. https://grist.org/culture/survey-cop26-people-dont-want-to-change-habits-for-the-climate/. Accessed 7 Jan 2024.

[4] Markman A (2018) Why People Aren't Motivated to Address Climate Change. https://hbr.org/2018/10/why-people-arent-motivated-to-address-climate-change. Accessed 7 Jan 2024.

[5] Rismayani, Paliling A, Nurhidayani A, et al. (2022) Fundamental Design of Flood Management Educational Games Using Virtual Reality Technology. Int J Online Biomed Eng (iJOE) 18:19–32.

[6] Amit E, Algom D, Trope Y (2009) Distance-Dependent Processing of Pictures and Words. J Exp Psychol Gen 138:400–415.

[7] Santoso M, Bailenson J (2025) Virtual Reality Experiences to Promote Environmental Climate Citizenship. Handbook of Climate Change Mitigation and Adaptation:365–407.

[8] Tanbour E, Almousa OF, Korkmaz K, et al. (2024) Virtual reality simulation of highway bridges as a teaching tool in engineering. J Constr Eng Manag Innov 7:1–9.

[9] Schott C (2017) Virtual fieldtrips and climate change education for tourism students. J Hosp Leis Sport Tour Educ 21:13–22.

[10] Petersen GB, Klingenberg S, Mayer RE, et al. (2020) The virtual field trip: Investigating how to optimize immersive virtual learning in climate change education. Br J Educ Technol 51:2099–2115.

[11] Calil J, Fauville G, Queiroz ACM, et al. (2021) Using Virtual Reality in Sea Level Rise Planning and Community Engagement—An Overview. Water 13:1142.

[12] Yavo-Ayalon S, Joshi S, Zhang Y, et al. (2023) Building Community Resiliency through Immersive Communal Extended Reality (CXR). Multimodal Technol Interact 7:43.

[13] Dhunnoo Y, Carter A, O'Hare D, et al. (2023) Improving Climate Change Awareness through Immersive Virtual Reality Communication: A Case Study. Sustainability 15:12969.

[14] Erisen E, Yildirim F, Duran E, et al. (2024) Exploring the effectiveness of virtual reality in combating misinformation on climate change. Polit Psychol 47.

[15] Meijers MHC, Torfadóttir R "Heather", Wonneberger A, et al. (2023) Experiencing Climate Change Virtually: The Effects of Virtual Reality on Climate Change Related Cognitions, Emotions, and Behavior. Environ Commun 17:581–601.

[16] Chandler T, Richards AE, Jenny B, et al. (2022) Immersive landscapes: modelling ecosystem reference conditions in virtual reality. Landsc Ecol 37:1293–1309.

[17] Huang J, Lucash MS, Scheller RM, et al. (2021) Walking through the forests of the future: using data-driven virtual reality to visualize forests under climate change. Int J Geogr Inf Sci 35:1155–1178.

[18] Carmona-Galindo VD, Velado-Cano MA, Groat-Carmona AM (2025) The Ecology of Climate Change: Using Virtual Reality to Share, Experience, and Cultivate Local and Global Perspectives. Educ Sci 15:290.

[19] Aksel Stenberdt V, Makransky G (2023) Mastery experiences in immersive virtual reality promote pro-environmental waste-sorting behavior. Comput Educ 198:104760.

[20] Cai Y, Wu X, Cao Q, et al. (2023) Designing Immersive Virtual Reality Simulation for Environmental Science Education. Electronics 12:315.

[21] Calvert J, Hume M (2023) Improving student learning outcomes using narrative virtual reality as pre-training. Virtual Real 27:2633–2648.

[22] Newton MH, Annetta LA, Bressler DM (2023) Using Extended Reality Technology in Traditional and Place-Based Environments to Study Climate Change. J Sci Educ Technol:1–20.

[23] Lo SC, Tsai HH (2022) Design of 3D Virtual Reality in the Metaverse for Environmental Conservation Education Based on Cognitive Theory. Sensors 22:8329.

[24] Markowitz DM, Laha R, Perone BP, et al. (2018) Immersive Virtual Reality field trips facilitate learning about climate change. Front Psychol 9:421569.

[25] Queiroz ACM, Fauville G, Abeles AT, et al. (2023) The Efficacy of Virtual Reality in Climate Change Education Increases with Amount of Body Movement and Message Specificity. Sustainability 15:5814.

[26] Vassilopoulos A, Papadaki L, Koundouri P (2023) Can virtual reality nudge toward green investing? An experiment with small business entrepreneurs. Rev Behav Finance, ahead-of-print. Epub ahead of print 2023. DOI: 10.1108/RBF-01-2023-0005/FULL/PDF.

[27] Thoma SP, Hartmann M, Christen J, et al. (2023) Increasing awareness of climate change with immersive virtual reality. Front Virtual Real 4:897034.

[28] Barnidge M, Sherrill LA, Kim B, et al. (2022) The Effects of Virtual Reality News on Learning about Climate Change. Mass Commun Soc 25:1–24.

[29] Contini G, Grandi F, Peruzzini M (2025) Human-Centric Green Design for automatic production lines: Using virtual and augmented reality to integrate industrial data and promote sustainability. J Ind Inf Integr 44:100801.

[30] Bachu D (2020) Awareness Doesn't Trigger Behaviour Change. https://www.linkedin.com/pulse/awareness-doesnt-trigger-behaviour-change-deepa-bachu/. Accessed 28 Jan 2024.

[31] Wolf M, Teizer J, Wolf B, et al. (2022) Investigating hazard recognition in augmented virtuality for personalized feedback in construction safety education and training. Adv Eng Inform 51:101469.

[32] Urban H, Pelikan G, Schranz C (2022) Augmented Reality in AEC Education: A Case Study. Buildings 12:391.

[33] Chu CH, Liao CJ, Lin SC (2020) Comparing augmented reality-assisted assembly functions-A case study on Dougong structure. Appl Sci (Switzerland) 10. Epub ahead of print 2020. DOI: 10.3390/APP10103383.

[34] Deshpande A, Kim I (2018) The effects of augmented reality on improving spatial problem solving for object assembly. Adv Eng Inform 38:760–755.

[35] Christiano A, Neimand A (2017) Stop Raising Awareness Already. https://ssir.org/articles/entry/stop_raising_awareness_already#. Accessed 28 Jan 2024.

[36] Atakli G, Kuran H, Kent KÜ, et al. (2022) İklim Değişikliği Farkındalık Ölçeğinin Geliştirilmesi. Biyolojik Çeşitlilik ve Koruma 15:150–161.

[37] Pfeffer J, Sutton R (2000) THE KNOWING - DOING GAP: How Smart Companies Turn Knowledge into Action. Hardvard Business School Press.